NASA SP-5973 (01)

TECHNOLOGY UTILIZATION

# PHYSICAL SCIENCES: THERMODYNAMICS, CRYOGENICS, AND VACUUM TECHNOLOGY

(NASA-SP-5973(01)) PHYSICAL SCIENCES: THERMODYNAMICS, CRYOGENICS, AND VACUUM TECHNOLOGY: A COMPILATION Technology Utilization (NASA) 26 p HC $1.00 CSCL 20M G1/23

N74-34173

Unclas 49413

## A COMPILATION



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

# Foreword

The National Aeronautics and Space Administration has established a Technology Utilization Program for the dissemination of information on technological developments which have potential utility outside the aerospace community. By encouraging multiple application of the results of its research and development, NASA earns for the public an increased return on the investment in aerospace research and development programs.

This Compilation is one of a series of documents intended to present such information. It includes a collection of innovations developed by NASA and its contractors in thermal and vacuum technology. This Compilation is divided into three sections. Section One describes a variety of thermodynamic devices including heat pipes and cooling systems. The second section presents a number of new methods of handling cryogenic fluids. Section Three describes several vacuum devices and systems adapted for use in a vacuum.

Additional technical information on individual devices and techniques can be requested by circling the appropriate number on the Reader Service Card included in this Compilation.

The latest patent information available at the final preparation of this Compilation is presented on the page following the last article in the text. For those innovations on which NASA has decided not to apply for a patent, a Patent Statement is not included. Potential users of items described herein should consult the cognizant organization for updated patent information at that time.

We appreciate comment by readers and welcome hearing about the relevance and utility of the information in this Compilation.

Jeffrey T. Hamilton, *Director*
*Technology Utilization Office*
*National Aeronautics and Space Administration*



For sale by the National Technical Information Service, Springfield, Virginia 22151. $1.00

# Contents


| | Page |
|---|---|
| SECTION 1. THERMODYNAMIC DEVICES | |
| A Method for Increasing Cooling-Gas Flow in Rice and Lundell Alternators | 1 |
| An Efficient Heat-Recovery System | 2 |
| Coldplate Heat-Exchanger Engine Radiator | 3 |
| An Economical Engine Oil Heater: A Concept | 4 |
| Design of Baffles for Pin-Fin Coldplates | 5 |
| A Universal Joint to Transmit Heat | 6 |
| An Aluminum Heat Pipe | 7 |
| Regenerative Coolant Tube | 7 |
| Heat Sinks for Magnetic Components | 8 |
| Thermal Conductance of Bolted Joints | 9 |
| Crossflow Theory: A Study | 9 |
| Concentric-Shell-Tube Heat Exchanger | 10 |
| Reducing Thermal Expansion of Phase-Change Materials | 10 |
| SECTION 2. CRYOGENICS | |
| A New Technique Improves Ultimate Pumping Capabilities of a Cryosorption Pump | 11 |
| Cryogenic Surface-Tension/Start Tank | 12 |
| Flow Control of Cryogenic Fluids | 13 |
| Liquid Nitrogen Safety-Fill Hood | 14 |
| SECTION 3. VACUUM TECHNOLOGY | |
| Aluminum Plating of High-Vacuum Chambers | 15 |
| Vacuum-Evaporation Source Holder | 16 |
| Fiberglass Vacuum Tank | 17 |
| A Secondary Standard for Ultrahigh Vacuum | 18 |
| X-Ray Anode Fine Adjustment | 20 |
| PATENT INFORMATION | 21 |

# Section 1. Thermodynamic Devices

## A METHOD FOR INCREASING COOLING-GAS FLOW IN RICE AND LUNDELL ALTERNATORS

An increase in the cooling-gas flow, with virtually no increase in windage loss, is required to achieve adequate cooling in Rice and Lundell alternators. This cooling-gas flow can be approximately doubled by generating a turbulent flow of the gas at the entrance of the flow gap between the conductors. This method may be useful for other applications where it is desirable to extract maximum gas flow from a high-tangential-velocity stream where radial space is at a premium.

Much of the heat loss generated in Rice and Lundell alternators used in closed Brayton systems is removed by gas flow. This flow is induced around an internal closed loop by pressure differences generated by conical surfaces on the rotor. The gas flow is accelerated to a high-tangential velocity by the rotation of the rotor (see Figure 1). However,

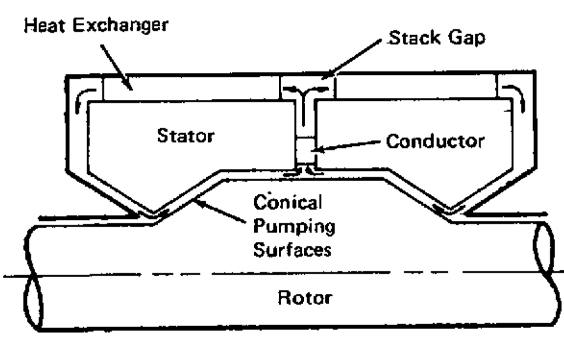



Figure 1. Cooling-Gas Flow Path

to complete the flow circuit, the gas must leave the gap between the rotor and the stator by flowing radially outward between the rounded conductors. Because only a very small pressure drop is generated by the conical pumping surface, careful attention must be paid to the design of the flow area between the conductors, to achieve sufficiently-high gas-flow rates for cooling. Ideally, turning vanes and a diffuser section would be most conducive to a high flow rate, but the electrical design of the system requires that the conductors be placed close to the stator bore. This close proximity of the conductors to the cooling flow gap and the small distance between conductors preclude the use of turning vanes and a diffuser section.

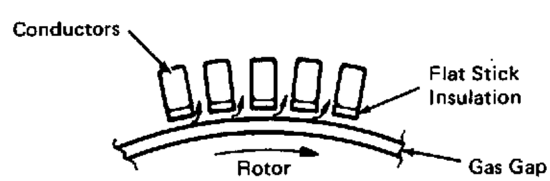



Figure 2. Placement of Sharp-Cornered Insulation Sticks

Experiments have been conducted to find a suitable way of achieving the required increase in cooling-gas flow. It was determined that flat sharp-cornered insulation sticks (see Figure 2) placed along the innermost edge of the conductors apparently generated a turbulent boundary layer which approximately doubled the cooling-gas flow.

Source: F. X. Dobler of
Garrett Corp.
under contract to
Lewis Research Center
(LEW-11867)

*No further documentation is available.*

# AN EFFICIENT HEAT-RECOVERY SYSTEM

A new variable-conductance heat-pipe header is able to supply and control up to two kilowatts of heat to a large radiator panel. It can also serve as an alternative to a pumped-fluid loop system, for transporting large amounts of heat.

The heat pipe is able to conduct large amounts of heat at a variable rate through the use of a tunnel wick. The tunnel wick is a self-priming composite structure that runs the length of a hollow tunnel. The tunnel is primed by a temperature-induced pressure difference in the pipe. The size of the pipe is not limited, therefore, by the requirement for surface-tension priming, as are standard heat-pipe sizes.

Under a maximum load, the heat pipe has a very high conductance and a correspondingly low temperature. Under partial loads, the heat pipe progressively shuts off the radiator through small drops in evaporator temperature.

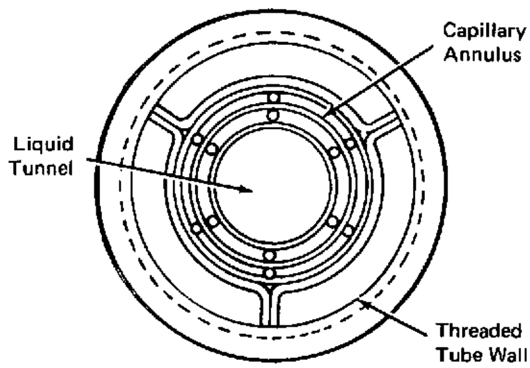



Figure 1. Tunnel Wick

The tunnel wick (see Figure 1) is framed by wrapping screens and spacers on a mandrel (which is subsequently removed). The wick is inserted in a retainer that supports it symmetrically within the pipe. The retainer may have twelve or more legs, which serve as a path for liquid flow between the wick and the fine circumferential grooves in the wall. The reservoir contains a wick that connects with the main transport wick and is kept colder than the condenser, to provide a known, controllable, vapor partial pressure.

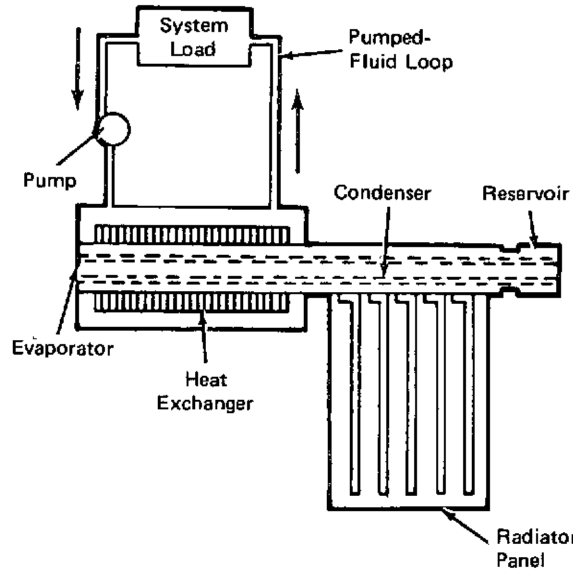



Figure 2. Heat-Pipe System

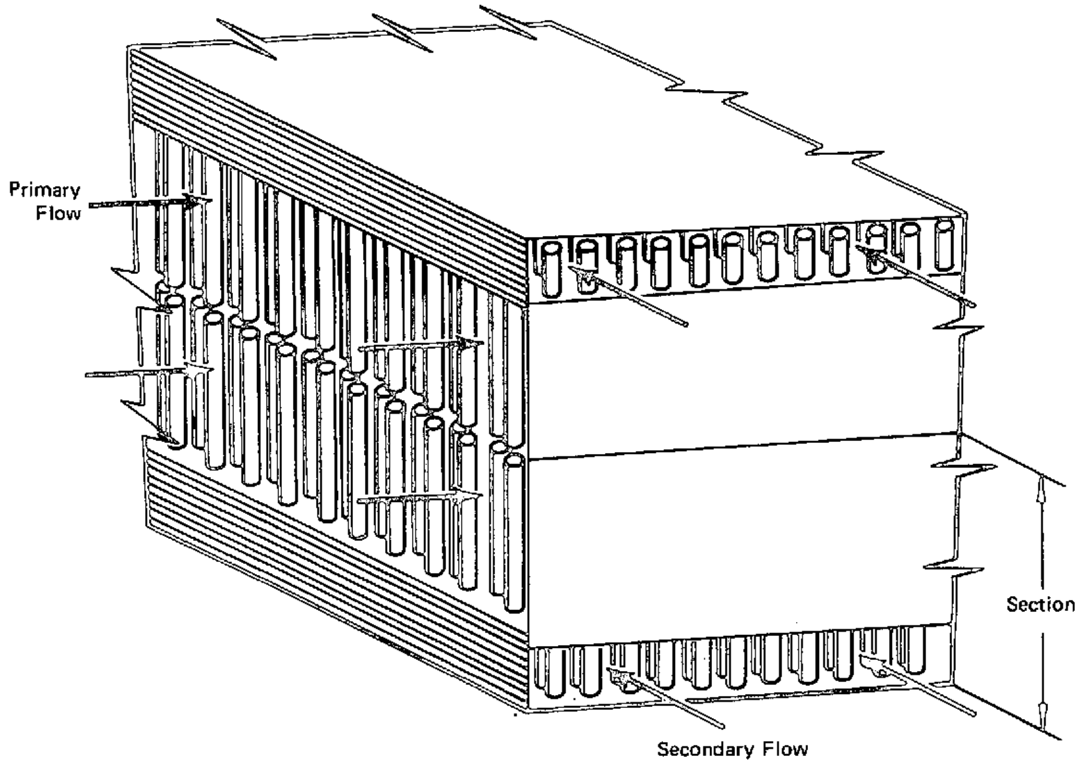
A system using the heat pipe is shown in Figure 2. The evaporator connects with the pumped-fluid loop, to pick up heat through a heat exchanger and a high-conductance maintainable joint. The condenser connects to feeder pipes on the radiator panel. The panel heat pipes all run at the same temperature: somewhat below the temperature of the pumped-fluid outlet. The shutoff pipes are at a temperature close to that of the environment, and the reservoir is thermally isolated from the rest of the pipe.

In an actual system, a 2.54-cm (1-in.) nominal ID ammonia heat pipe, with a 122-cm (4-ft) evaporator and a 122-cm condenser, provided an overall temperature drop (from the outside of the evaporator to the outside wall of the condenser) of approximately 1.9° C (3.5° F) per kilowatt of load.

Source: R. Kosson, M. Tawil, and F. Edelstein of Grumman Aerospace Corp. under contract to Marshall Space Flight Center (MFS-22506)

*Circle 1 on Reader Service Card.*

## COLDPLATE HEAT-EXCHANGER ENGINE RADIATOR




Car-Radiator Section with Pin-Fin Double-Flow Heat Exchanger

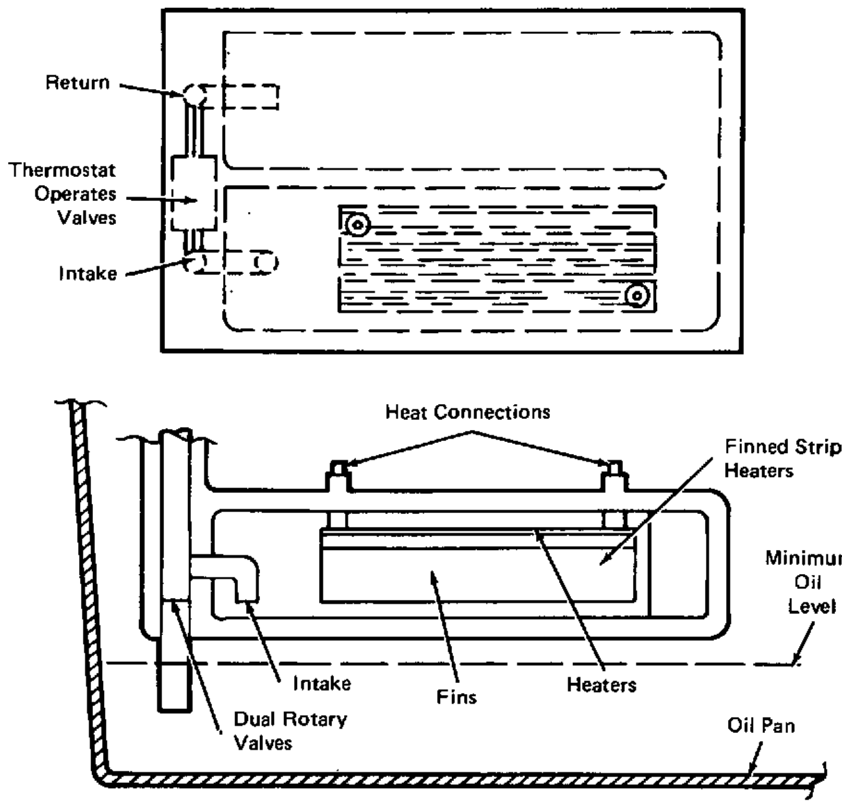
A new concept in engine radiators is essentially a sandwiched double-flow coldplate heat exchanger. A system with a 51- by 51- by 5-cm (20- by 20- by 2-in.) core size is calculated to have a heat flux of $3.65 \times 10^6$ J/hr (3460 BTU/hr). A radiator can consist of several of these sections.

A section of the new radiator is shown in the illustration. The pin fins transfer heat from the liquid (for instance, water in an automobile engine) to the gas (e.g., air). The pin length exposed to the air is 1.27 cm (0.50 in.) and the length exposed to the liquid is 0.318 cm (0.125 in.). A single plate bonds the pins on the water side of the coldplate. Both sides of the plate are at the same pressure, and the plate therefore can be quite thin (0.975 cm) to save weight. In addition, sufficient clearance exists between pins of adjacent coldplates to minimize boundary-layer buildup around the pins and increase the overall thermal performance of the heat exchanger.

Source: F. P. Georgatsos of
Rockwell International Corp.
under contract to
Johnson Space Center
(MSC-19115)

*Circle 2 on Reader Service Card.*

## AN ECONOMICAL ENGINE OIL HEATER: A CONCEPT




Concept For Engine Oil Heater Requiring Minimum Heater Capacity

Various types of oil preheaters are available. Small heaters to replace dipsticks have been sold for cars, but heat loss from the oil pans in cold weather makes large heaters essential. A new design has overcome this problem.

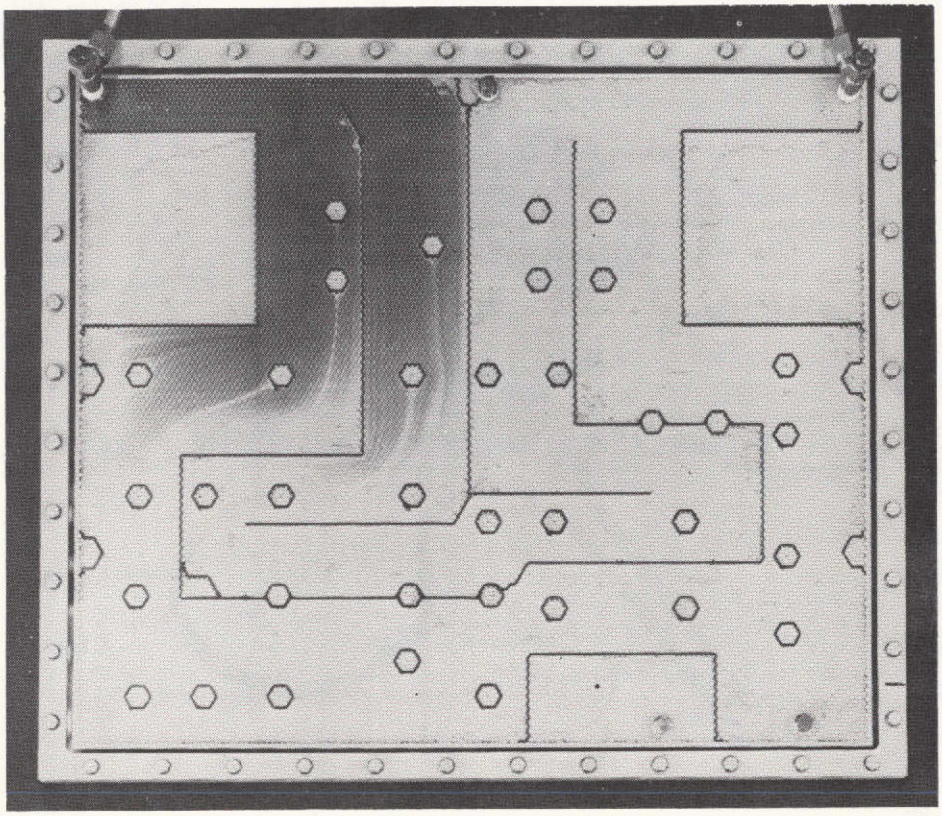
This new heater is a foam-insulated container using fin-type electrical heaters (see figure). A small volume of oil is insulated with a rigid chemically-resistant polyurethane foam.

Gradual circulation of the entire oil supply is controlled by a thermostatic valve. This design is made possible through the use of ultrasafe electric strip heaters and chemically-resistant polyurethane materials. The new oil heater will provide warm oil for easy engine starts with minimum heating.

Source: H. Dirnbach, L. G. Lanier, and
E. C. Briggs of
Rockwell International Corp.
under contract to
Johnson Space Center
(MSC-17657)

*No further documentation is available.*

## DESIGN OF BAFFLES FOR PIN-FIN COLDPLATES



Pin-Fin Coldplate

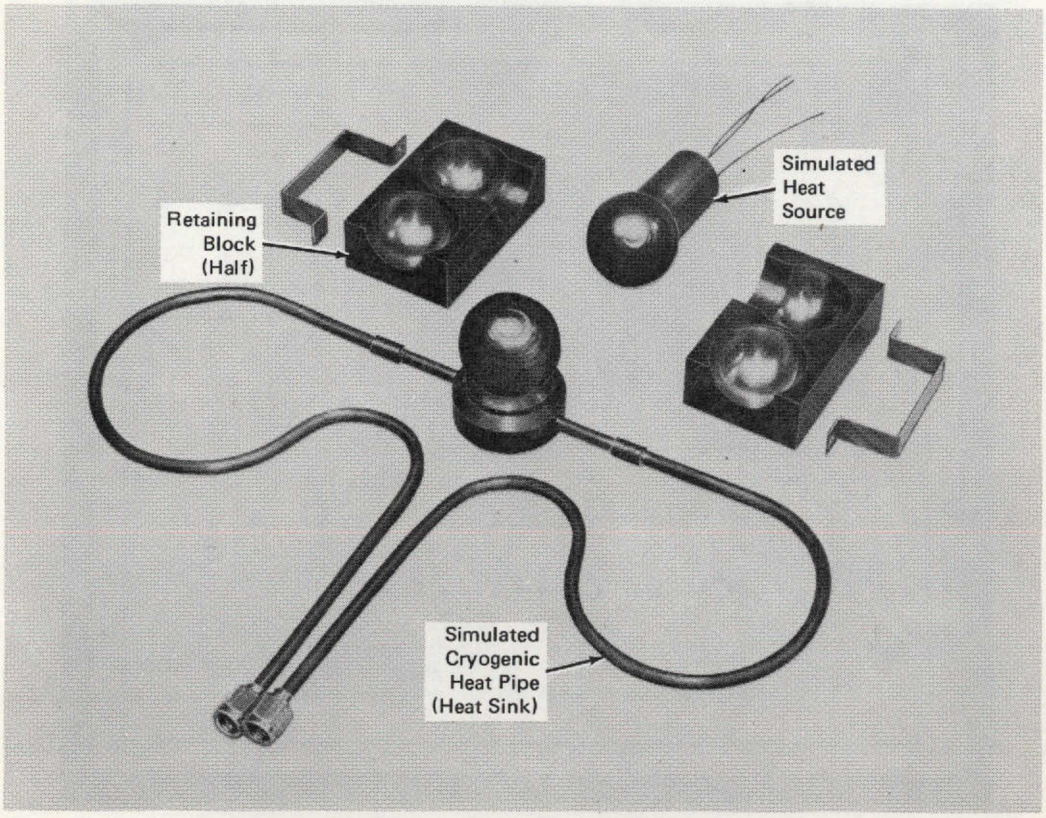
A technique has been devised to aid in the design of pin-fin-type coldplates. A 61- by 61-cm (2- by 2-ft) pin-fin coldplate is fabricated with a transparent Plexiglas cover (see figure). A test coldplate is modified to represent variously sized and shaped coldplates and various baffle designs, by inserting rubber strips to act as adjustable boundaries. Inlet and outlet lines are attached to the 1.27-cm (0.5-in.) Plexiglas cover. The flow of coolant is made visible by injecting a solution of methyl blue dye crystals. The Plexiglas is kept from bulging under pressure by connecting the system outlet to an evacuated container.

This method should minimize costs, parts, and setup time in baffle design.

Source: G. C. Schaedle, W. A. MacPherson, W. F. Dyer, and R. P. Arras of Rockwell International Corp. under contract to Johnson Space Center (MSC-15112)

*No further documentation is available.*

## A UNIVERSAL JOINT TO TRANSMIT HEAT




Universal Joint to Transmit Heat at Cryogenic Temperatures

A universal joint can be used to transmit heat at cryogenic temperatures. The joint allows rotation about three axes, and it works with a very small temperature difference. Previously, movable heat-transfer systems consisted of battery cables or bellows. These both require a greater temperature difference and are not as flexible as the universal joint; furthermore, the bellows and the cable are both damaged by heavy wear.

The universal joint consists of two spherical parts (see figure). One part is rigidly attached to a component, such as a cryogenic engine, the other part is connected to a heat pipe. The two spheres are held by a pair of blocks with spherical indentations. A limited-movement spring holds the blocks firmly against the spheres; and a lubricant, molybdenum disulphide, is burnished on the spherical surfaces to allow free movement of the ball joints. Heat is transferred from one rigid component to another through the spring-loaded blocks, which are made of a heat-conducting material such as copper.

Source: M. G. Gasser
Goddard Space Flight Center
(GSC-11405)

*No further documentation is available.*

## VACUUM-EVAPORATION SOURCE HOLDER

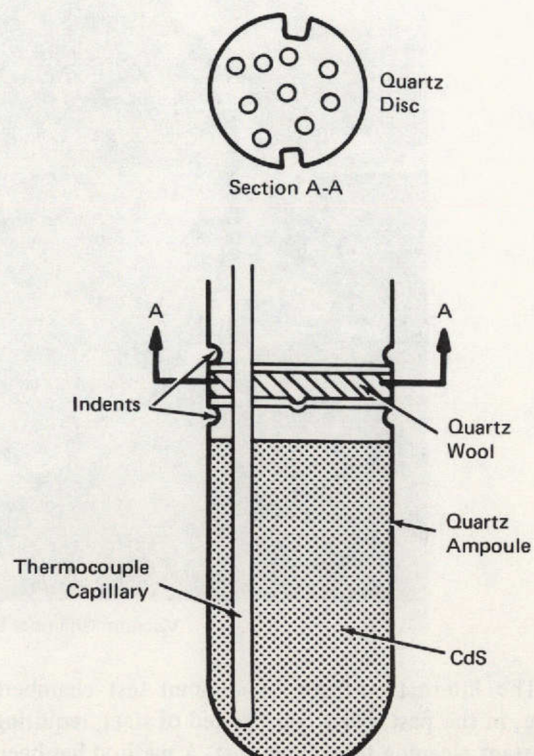
A new quartz ampoule, for holding cadmium sulfide used in vacuum-evaporation systems, successfully contains ejected particles and has a long use life (30 to 40 runs). Cadmium sulfide is among the compounds being studied for use in solar cells and semiconductors. Materials used for these purposes are vacuum deposited on substrates to form thin films, 10 to 30 microns thick. Cadmium sulfide, to be effective, must be evaporated at very high rates (50 to 1000 angstroms per second). However, these high evaporation rates cause excessive outgassing of the CdS, and ejected particles of unvaporized CdS can severely damage the film being formed. Also, the sulfur component in CdS causes rapid deterioration of source-holder materials such as tantalum and molybdenum, limiting their life to from two to five runs.

Previous approaches to this problem employed quartz ampoules, conventionally used to contain volatile and/or corrosive materials, with constricted exits plugged with quartz wool, to limit the passage of "spitting" particles. The effectiveness of the quartz wool plugs depends on their density. Uniform density is difficult to maintain; and, at best, the plugs do not effectively prevent the ejection of particles.

In the new source holder (see figure), the constricted exit and the quartz-wool plug are replaced with a "twist-lock top" which effectively contains "spitting" particles. The top consists of a pair of perforated discs with the space between them filled with quartz wool. Notches in the top fit into tabs located at the mouth of the ampoule. In use, the ampoule is loaded, and the top is slipped into place and locked by twisting a quarter-turn, which offsets the top set of holes relative to the bottom set of holes. The quartz wool held in place between the discs is not disturbed. The combination of the quartz wool and the offset perforations in the discs above and below the wool effectively stops "spitting" particles and serves to distribute the evaporated material more evenly.

Prototype ampoules are sized to fit into conventional heaters. The discs are perforated with 3-mm-diameter holes to provide a total open area equal to 25 percent of the disc surface. In use, these ampoules, loaded with 60 grams of CdS, produce films up to 30 microns thick on a 58-$cm^2$ (9-$in.^2$) substrate. The proper sizes and dimensions of ampoules and their tops for other uses depend on the material to be evaporated, the rate of evaporation, and the desired rate of transmission through the disc-wool assembly.

This technique is applicable to most vacuum-deposition processes involving highly-reactive, high-vapor-pressure compounds that tend to "spit" when heated.



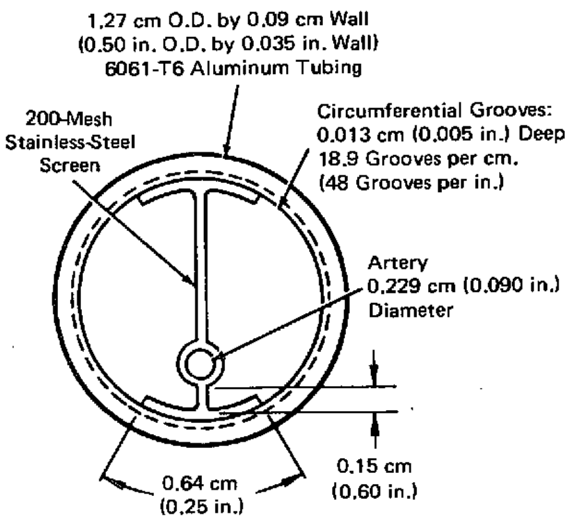

Quartz-Disc Evaporation Ampoule

Source: John A. Scott-Monck and Gerald A. Roberts of TRW, Inc. under contract to Lewis Research Center (LEW-11566)

*No further documentation is available.*

## AN ALUMINUM HEAT PIPE

An aluminum heat pipe having a composite wick structure has been developed. The wick structure of most heat pipes is cylindrical and lines the inside diameters of the pipes. Heat pipes utilizing composite wicks afford the same degree of isothermalization as conventional pipes, and have a significantly higher heat-transport capability. In addition, a larger pumping pressure can be obtained without incurring excessive viscous losses.




Arterial Composite-Wick Configuration

The composite wick structure that has been fabricated is of the arterial type (see figure). A 90-mil (0.23-cm) artery is formed from 200-mesh stainless-steel screen. The artery is offset approximately 60 mils (0.15 cm) from the wall, so that boiling which occurs near the wall will not disrupt the pumping. The wick is contained in an aluminum tube having an outside diameter of 0.50 in. (1.27 cm). The artery has been operated with various liquids. A heat transport in excess of 36,000 watt-inches can be achieved with ammonia.

Heat pipes of this type may be used wherever large heat loads or transport lengths are involved. They may be useful in heat exchangers and in heating and air-conditioning equipment.

Source: Dynatherm Corp.
under contract to
Goddard Space Flight Center
(GSC-11361)

*No further documentation is available.*

## REGENERATIVE COOLANT TUBE

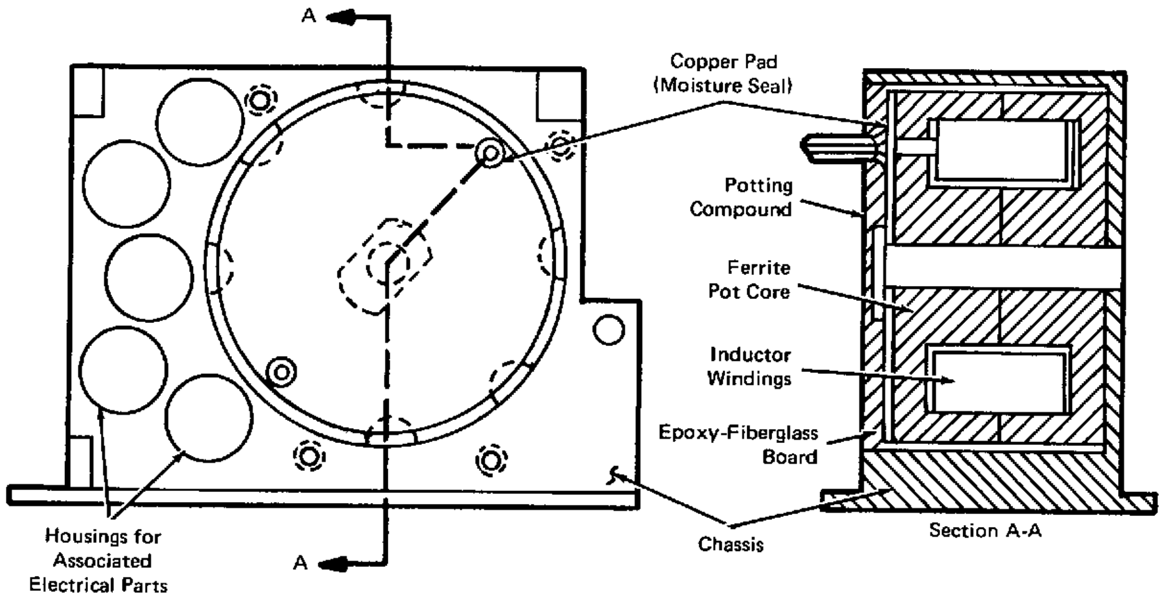
Regenerative cooling of high-heat-flux heat-transfer devices requires very critical control of flow velocities to optimize system efficiencies. This is normally accomplished by varying the cross-sectional area of the flow passage for the coolant. Previously, seamless tubing has been tapered, by a series of expensive machine operations, to achieve this variation in area.

A new method of varying the cross-sectional area has been developed. A portion of the tube wall is cut away and replaced by a flat plate, resulting in a D-shaped flow area. A high-integrity cover is provided by electroforming directly to the edges of the cut. Area control is maintained by varying the depth of the cut. A prototype panel of tubes has been tested hydrostatically to 7500 psi ($52 \times 10^6$ N/m$^2$) successfully.

Source: J. G. Vehige of
Rockwell International Corp.
under contract to
NASA Headquarters
(HQN-10284)

*Circle 3 on Reader Service Card.*

# HEAT SINKS FOR MAGNETIC COMPONENTS




A Typical Inductor Assembly

Power-supply inductors and transformers are conventionally potted and packaged at less than optimum efficiency. A large amount of potting is used, and it is surrounded by an insulated case. Heat buildup is extensive, since the potting and case are poor heat conductors. In addition, the potting is not an effective hermetic seal.

A new packaging method has been used to overcome these difficulties. The inductor is fabricated with a ferrite pot core and is potted directly to the chassis, which serves as a heat sink. An added bonus is better shielding than in the conventional configuration; stray EMF is confined to the pot-core inductor.

Moisture is excluded by using a solder joint as a moisture seal. An epoxy-fiberglass copper-clad board is placed over the inductor (see figure). Input and output wires are soldered to copper pads on the board.

To free the epoxy resin of air bubbles, the entire assembly is put into a vacuum chamber immediately after the resin has been poured. The chamber is evacuated to $10^{-6}$ torr, forcing all air bubbles out of the resin.

Source: D. Williams and H. Frankland of
Teledyne Ryan Aeronautical Co.
under contract to
Johnson Space Center
(MSC-12374)

*Circle 4 on Reader Service Card.*

## THERMAL CONDUCTANCE OF BOLTED JOINTS

The general uncertainty in the heat conductance of bolted joints imposes a serious limitation on design engineers. Previously, there existed no single reliable source which provided a compilation of heat-transfer data in useful form. This limitation often resulted in design changes or in overconservative design.

A study of contact-conductance data for bolted joints has now been made. A report on this study reveals that, currently, there are no existing analytical methods of predicting thermal conductance. There are, however, empirical results and approaches which lead to useful approximation methods. The problem is complicated by the large number of parameters involved. Structural effects (such as plate deformation under load, surface characteristics, and finish) determine contact area, which is in turn affected by thermal expansion and nonuniform heating.

The report presents pertinent results in tables and graphs. A summarization of surface properties, loads and distribution, and heat transfer is made. Thermal tests are rated with respect to reliability. Various joint geometries and materials are also treated. General guidelines are presented which provide the engineer with a determination, or at least an estimation, of the heat properties of the joint in question. Explicit procedures for using the guidelines are presented for a variety of structural geometries. A bibliography also is included.

Source: E. Fried of
General Electric Co.
under contract to
Marshall Space Flight Center
(MFS-22120)

*Circle 5 on Reader Service Card.*

## CROSSFLOW THEORY: A STUDY

A report is available describing a technique for approximating the effects of crossflow on heating and boundary-layer transitions along the windward centerline of delta platforms and flat plates of finite width. The technique does not require numerical computer integration, as it depends upon closed-form solutions of integral equations.

Heat flux is taken to be inversely proportional to the "effective" wetted distance to some power. The crossflow velocity gradient is assumed to be analogous to that at the stagnation point of a disk normal to the free-stream velocity vector. The "effective" lengths of crossflow are obtained by integrating expressions for the laminar and turbulent flows in terms of a streamline divergence parameter.

The study concludes that:

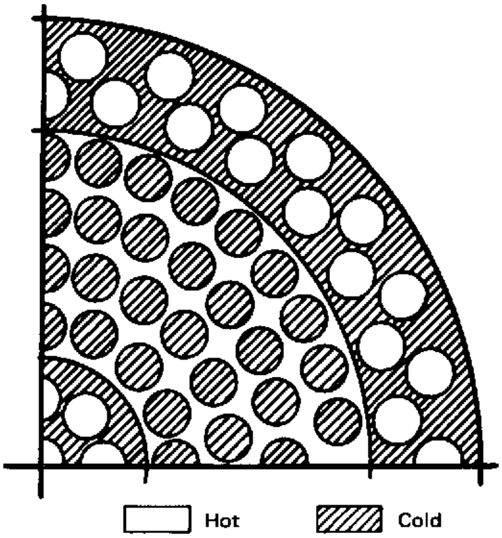
a. Allowing for crossflow increases heating rates and delays transition;
b. The influence on heating is more significant for laminar flow than for turbulent flow; and
c. The effects are attributed to a decrease in mass flow in the boundary layer.

Source: L. C. Baranowski of
McDonnell Douglas Corp.
under contract to
Marshall Space Flight Center
(MFS-21887)

*Circle 6 on Reader Service Card.*

## CONCENTRIC-SHELL-TUBE HEAT EXCHANGER

A widely used type of heat exchange is the shell-and-tube type. One fluid flows inside of the tubes while a second fluid is forced through the shell and over the outsides of the tubes. Another common type of heat exchanger is the concentric-circular-tube type. In this design, hot and cold fluids flow in the alternate annular areas formed by concentric tubes.




Concentric-Shell-Tube Heat Exchanger

A heat exchanger has been developed utilizing both of these configurations (see figure). This concentric-shell-tube heat exchanger provides a considerable increase in the amount of heat transfer, and it needs less surface area for a given amount of heat. It is easier to fabricate, has less leakage, and has a smaller pressure drop than conventional designs.

Cold gas flows in the inner and outer shells, and hot gas flows in the middle shell. The tubes in the inner and outer shells carry hot gas, and those in the middle carry cold gas. Gas in each shell exchanges heat with gas in the other shells, as well as with gas in the tubes.

Source: B. K. Singh of
Sperry Rand Corp.
under contract to
Marshall Space Flight Center
(MFS-22598)

*Circle 7 on Reader Service Card.*

## REDUCING THERMAL EXPANSION OF PHASE-CHANGE MATERIALS

Phase-change materials (PCM) are used as heat exchangers, when suitably packaged and placed in contact with heat sources. A material that changes phase at the temperature of interest can use the heat of fusion, or heat of melting, to cool or heat the exchange medium. One problem involved in the design of a package to contain the PCM concerns the thermal expansion of the material; under certain circumstances, the container may be ruptured.

A technique has been devised for reducing the thermal expansion of materials that go through a solid-liquid phase change. This is accomplished by adding a gelling agent to such a material in the liquid phase, generally in a 1- to 10-percent concentration. The gelled material will have a lower density than the pure material and will allow room for internal expansion. This increases compressibility and reduces force on container walls.

This method has been applied to tridecane in a thermal storage device. Measurements indicate that thermal expansion was reduced to between 3 and 5 percent from usual values of 7 to 8 percent, when measured from 5.5 K (10° F) below to 36 K (65° F) above the fusion point of tridecane. This method will work wherever phase-change materials are used.

Source: G. P. Lang of
McDonnell Douglas Corp.
under contract to
Marshall Space Flight Center
(MFS-22215)

*Circle 8 on Reader Service Card.*

# Section 2. Cryogenics

## A NEW TECHNIQUE IMPROVES ULTIMATE PUMPING CAPABILITIES OF A CRYOSORPTION PUMP

This technique was developed to improve the ultimate background pressure of a nitrogen cryosorption pump used to pump an ultrahigh vacuum chamber down to pressures around $10^{-7}$ torr, in order to facilitate the startup of an ion-pumping system.

The standard procedure for activating a $LN_2$ cryosorption pump is to heat it to the range of from 480 to 590 K (400° to 600° F), with the pump exhaust open to room conditions. Typically, the heating cycle lasts between 1 and 16 hours, after which the exhaust is closed, the heater turned off, and $LN_2$ cooling initiated. After one hour of cooling, the pump is usually ready for use. Activated in this manner, the ultimate blank-off pressure is only in the upper $10^{-4}$ torr range.

The lower pressure can be reached by pulling a vacuum on the sorption material while the pump is being heated. The resulting higher degree of degassing of the sorption material produces a higher pumping capability and a lower ultimate pressure at cryogenic temperatures. The time required to degas the material is proportional to the activation temperature, the pressure within the sorption pump, and the path length for the desorbing gas. By degassing the sorption material at the highest permissible temperature and under low pressure, it is possible to achieve an ultimate vacuum in the $10^{-7}$ torr range at cryogenic temperatures.

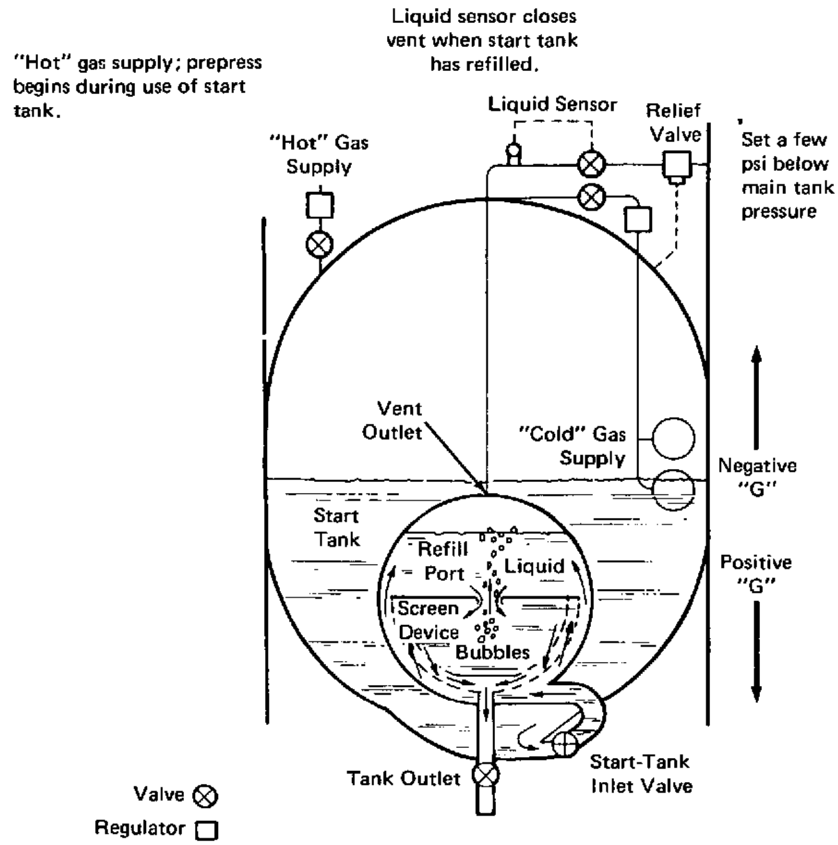
The critical factor in the procedure is the type of sorption material. The optimum material, based on use, cost, and safety, is zeolite. This material has an average pore size of five angstroms, although it is used as compacted porous pieces. Temperature, differential pressure, and diffusion time are major factors.

The sorption material can be degassed into another cryosorption pump or by an oil-roughing pump using a molecular sieve. The length of time required to activate the sorption material is dependent upon the duty cycle and the condition of the spent sorption material. Typically, zeolite sorption-pump material is activated by baking the sorption pump at 700 K (800° F) and maintaining a background pressure of less than five microns within the pump during the activation cycle. The activation of the sorption material is considered complete when the pump is valved off hot and maintains a background pressure of five microns. After the pump is activated at 700 K (800° F), it is chilled and maintained at cryogenic temperatures for one hour prior to actual system use. After cooling, the nitrogen cryosorption pump can be maintained at a vacuum level of $4 \times 10^{-7}$ torr.

Source: James E. Triner and
Thomas J. Riley
Lewis Research Center
(LEW-11695)

*No further documentation is available.*

## CRYOGENIC SURFACE-TENSION/START TANK




Cryogenic Start-Tank

A newly developed tank is suitable for long-term storage of cryogenics. It embodies all of the advantages of both a surface-tension device and a start tank, while avoiding their disadvantages. The tank can store cryogenics for long periods without the formation of excessive vapor, is refillable, and will retain its contents under high acceleration.

In standard cryogenic storage devices, heat flux and pressure decay cause the formation of vapor. The best currently available tank reduces vapor formation through the use of surface tension. However, the surface-tension device is directly connected to the tank and decreases in tank pressure result in liquid in the surface-tension device being displaced by boiloff vapors from the tank.

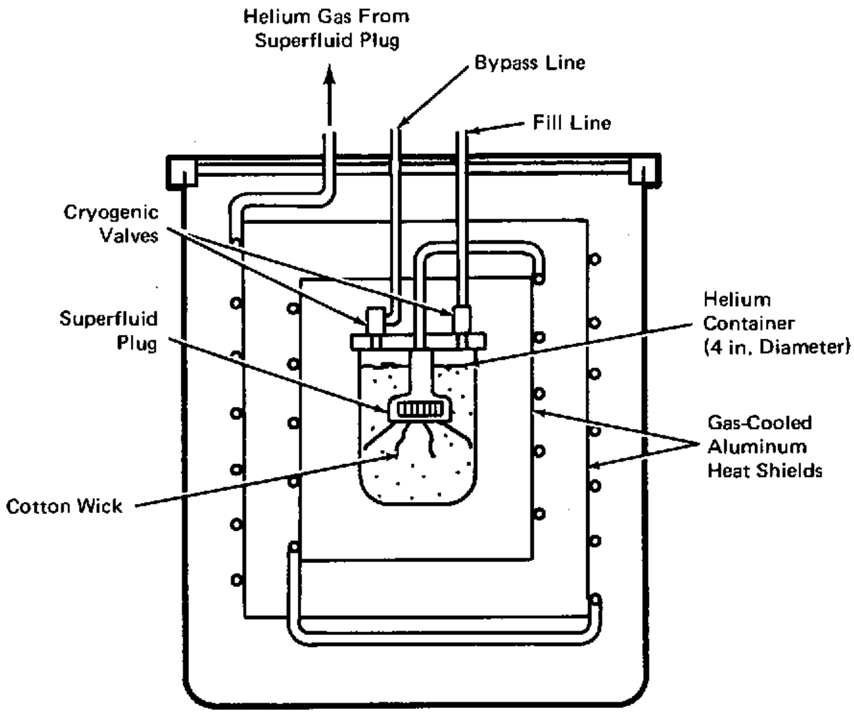
This new system (see figure) consists of a separate small tank, inside the main tank, with a positive expulsion device. Bellows, a bladder, or a reversing diaphragm may be used. A separate pressurization and venting system is used to refill the tank.

A screen serves as the surface-tension device, as in existing cryogenic storage systems, to hold vapor in the tank. If sufficient heat were to flow through the tank walls and cause vaporization to overcome the surface tension, only the liquid in the inner tank would be affected. Vaporization in this system does not affect the cryogenic fluid delivered from the system, since the retained liquid is located in the central region of the tank and will provide a purely liquid flow out of the system (even if no liquid is present between the screen and the tank wall).

Source: J. B. Blackmon, G. W. Burge, and J. N. Castle of McDonnell Douglas Corp. under contract to Marshall Space Flight Center (MFS-21566)

*Circle 9 on Reader Service Card.*

# FLOW CONTROL OF CRYOGENIC FLUIDS




Invertible Dewar

Conventional cryogenic technique involves the immersion of equipment in liquid helium and the withdrawal of boiled-off gas from the top of a Dewar flask (see figure). This technique requires gravitational phase separation of liquid from gaseous helium. Only gaseous helium is withdrawn from the vessel. A new system allows the Dewar to be used in any orientation or under conditions of zero gravity.

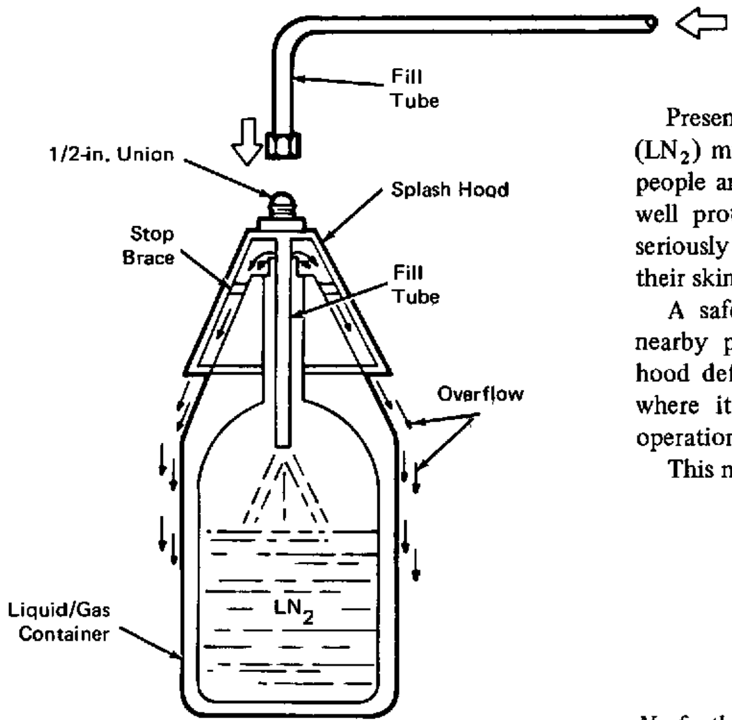
A high-thermal-conductivity porous plug conducts liquid helium to its outer surface where the helium evaporates and is withdrawn. The volume flow rate is controlled by the size of the plug and by the effective area of the channel it provides. Good results are obtained with a plug made from a tightly wound spool of 0.0013-cm (0.5-mil) aluminum foil. Approximately 200 layers are wrapped around a 3.175-cm (1.25-in.) mandril, providing a spacing of $10^{-4}$ cm ($4 \times 10^{-5}$ in.) between layers. The flow rate is approximately $2 \times 10^{-3}$ g/s at 2 K.

The system has been successfully tested in various orientations. With a larger plug, it should work well with normal fluids as well as cryogenic fluids.

Source: Peter M. Selzer, William Fairbank, and C. W. Francis Everitt of Stanford University under contract to NASA Headquarters (HQN-10693)

*Circle 10 on Reader Service Card.*

## LIQUID NITROGEN SAFETY-FILL HOOD




Liquid Nitrogen Hood

Presently, individuals handling liquid nitrogen ($LN_2$) must wear safety shields and gloves. However, people and equipment in the immediate area are not well protected. $LN_2$ may splatter into the air and seriously burn bystanders, if it comes in contact with their skins.

A safety hood has been developed to protect all nearby personnel during the handling of $LN_2$. The hood deflects splatter and boiloff towards the floor where it will not be dangerous (see figure). The operation is otherwise unaffected.

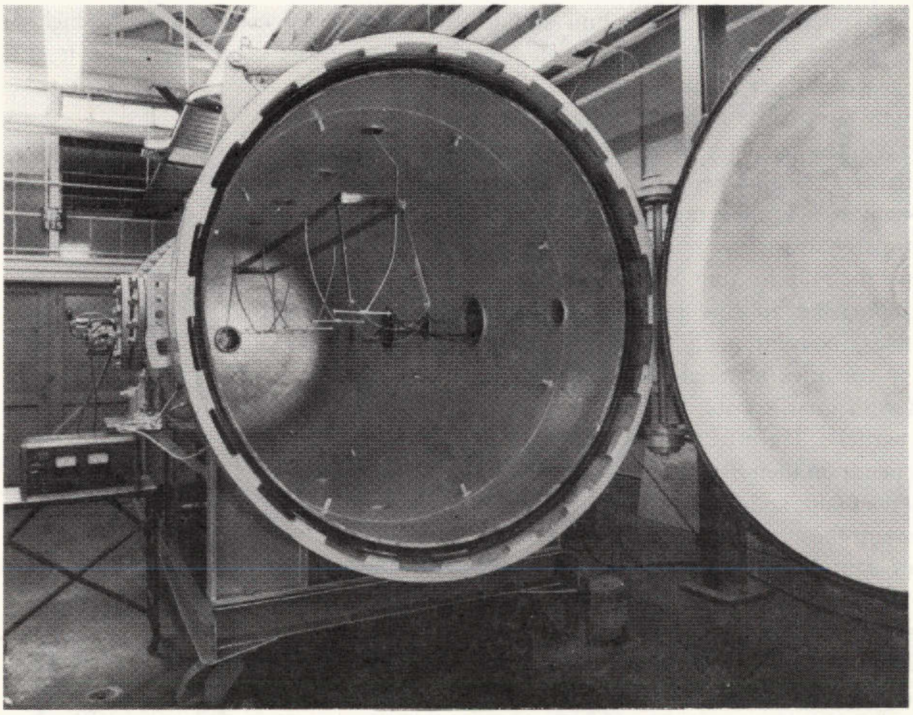
This method is applicable wherever $LN_2$ is used.

Source: L. O. Grand and B. T. Howland of
Rockwell International Corp.
under contract to
Johnson Space Center
(MSC-15868)

*No further documentation is available.*

# Section 3. Vacuum Technology

## ALUMINUM PLATING OF HIGH-VACUUM CHAMBERS



Vacuum Chamber With Tungsten Filaments

The internal surfaces of vacuum test chambers have, in the past, been constructed of steel, requiring constant cleaning to remove rust. A method has been developed for flash plating these chambers with aluminum. The aluminum does not rust and provides a highly reflective surface without additional surface area. The overall pumping load is reduced by the superior outgassing characteristics of the aluminum surface.

The plating is accomplished by evaporating aluminum under high vacuum. The internal surfaces of the chamber are first cleaned. Tungsten filaments are suspended inside the chamber (see figure), and aluminum staples are hung on the filaments. The chamber is then evacuated to 0.001 torr, and an electric current is applied to the filaments. This vaporizes the aluminum staples, which readily condense on the cold internal surface of the test chamber. This process is repeated (7 to 10 times) until a test patch shows the required surface buildup. The surface is buffed to increase reflectivity.

This method could be applied to autoclaves, to vacuum freezing and drying chambers, and to other vacuum equipment constructed of steel.

Source: F. Q. Banker and
O. W. Guetzkow of
Rockwell International Corp.
under contract to
Johnson Space Center
(MSC-15566)

*Circle 11 on Reader Service Card.*

## VACUUM-EVAPORATION SOURCE HOLDER

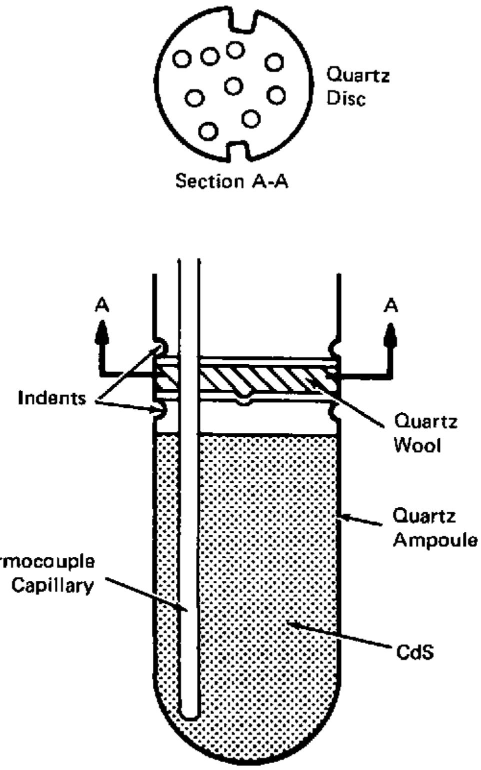
A new quartz ampoule, for holding cadmium sulfide used in vacuum-evaporation systems, successfully contains ejected particles and has a long use life (30 to 40 runs). Cadmium sulfide is among the compounds being studied for use in solar cells and semiconductors. Materials used for these purposes are vacuum deposited on substrates to form thin films, 10 to 30 microns thick. Cadmium sulfide, to be effective, must be evaporated at very high rates (50 to 1000 angstroms per second). However, these high evaporation rates cause excessive outgassing of the CdS, and ejected particles of unvaporized CdS can severely damage the film being formed. Also, the sulfur component in CdS causes rapid deterioration of source-holder materials such as tantalum and molybdenum, limiting their life to from two to five runs.

Previous approaches to this problem employed quartz ampoules, conventionally used to contain volatile and/or corrosive materials, with constricted exits plugged with quartz wool, to limit the passage of "spitting" particles. The effectiveness of the quartz wool plugs depends on their density. Uniform density is difficult to maintain; and, at best, the plugs do not effectively prevent the ejection of particles.

In the new source holder (see figure), the constricted exit and the quartz-wool plug are replaced with a "twist-lock top" which effectively contains "spitting" particles. The top consists of a pair of perforated discs with the space between them filled with quartz wool. Notches in the top fit into tabs located at the mouth of the ampoule. In use, the ampoule is loaded, and the top is slipped into place and locked by twisting a quarter-turn, which offsets the top set of holes relative to the bottom set of holes. The quartz wool held in place between the discs is not disturbed. The combination of the quartz wool and the offset perforations in the discs above and below the wool effectively stops "spitting" particles and serves to distribute the evaporated material more evenly.

Prototype ampoules are sized to fit into conventional heaters. The discs are perforated with 3-mm-diameter holes to provide a total open area equal to 25 percent of the disc surface. In use, these ampoules, loaded with 60 grams of CdS, produce films up to 30 microns thick on a 58-$cm^2$ (9-$in.^2$) substrate. The proper sizes and dimensions of ampoules and their tops for other uses depend on the material to be evaporated, the rate of evaporation, and the desired rate of transmission through the disc-wool assembly.

This technique is applicable to most vacuum-deposition processes involving highly-reactive, high-vapor-pressure compounds that tend to "spit" when heated.

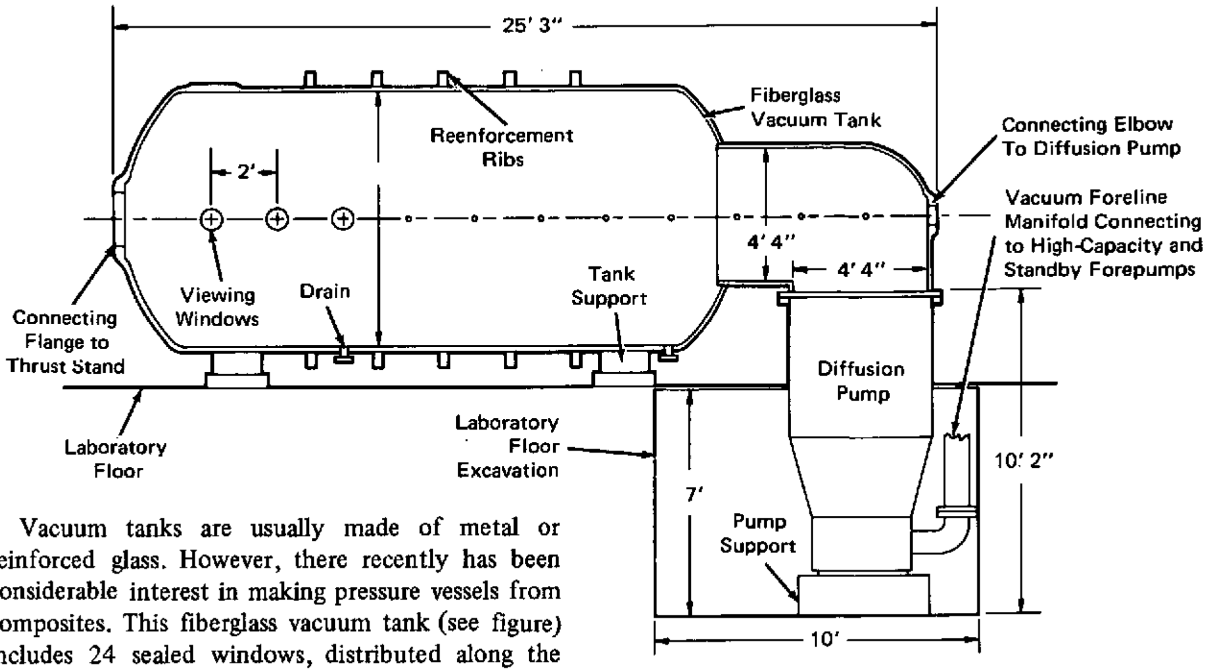



Quartz-Disc Evaporation Ampoule

Source: John A. Scott-Monck and Gerald A. Roberts of TRW, Inc. under contract to Lewis Research Center (LEW-11566)

*No further documentation is available.*

## FIBERGLASS VACUUM TANK




Vacuum tanks are usually made of metal or reinforced glass. However, there recently has been considerable interest in making pressure vessels from composites. This fiberglass vacuum tank (see figure) includes 24 sealed windows, distributed along the walls of the tank, to permit optical observation in any direction and the insertion of diagnostic probes. The inside of the tank is opaque black, in order to form a uniform contrasting background when pictures are taken; the outside is white. A cooling system with plastic tubes imbedded in the insulation has been designed but has not been included in this construction for reasons of cost. A cooling system is, however, a good and simple way to improve the vacuum attainable and permits the testing of higher power thrusters. Another solution studied was the placement of the refrigerant or the refrigerating coils outside of the tank walls to permit simpler construction and easier inspection.

The tank is manufactured beginning at the inside and building out, gradually increasing the thickness of the walls. For this reason, the first layer, which is constantly in direct contact with the tank vacuum, is the most important surface. A metal form is used initially; as soon as a substantially rigid layer of plastic material is deposited on the metal surface, the form is taken away, and the buildup of the successive layers is made directly on the first layer. The windows are made when the tank is completely finished. To improve the angle of view from each window, the sealing flanges are connected directly to the tank surface, eliminating the need for any intermediate pipe. This feature, which is desirable for taking wide-angle pictures, slightly increases the cost of the finished tank.

The basic material used in the tank is a polyester resin combined with ordinary fiberglass. The distribution of the various layers of plastics is as follows: The first layer sprayed over the mandrel is a black gel coat of polyester containing a small percentage of carbon black. The high reactivity of this material gives a higher density and a reduced outgassing. A layer of fiberglass is sprayed over this first support as soon as the mandrel is removed; then a rigid isophthalic polyester resin of high reactivity is superimposed. It has an especially long gel time, adapted for the fabrication of very large parts and high reactivity. This permits the outgassing under vacuum to be reduced to the minimum. Immediately over this laminating resin, a layer of fiberglass woven roving is applied, followed by another glaze coat of polyester. Finally, a white gel coat of polyester is sprayed on, to produce the final surface of the tank.

Source: A. C. Ducati and R. G. Jahn of
Geotel, Inc.
under contract to
NASA Headquarters
(HQN-10494)

*No further documentation is available.*

# A SECONDARY STANDARD FOR ULTRAHIGH VACUUM

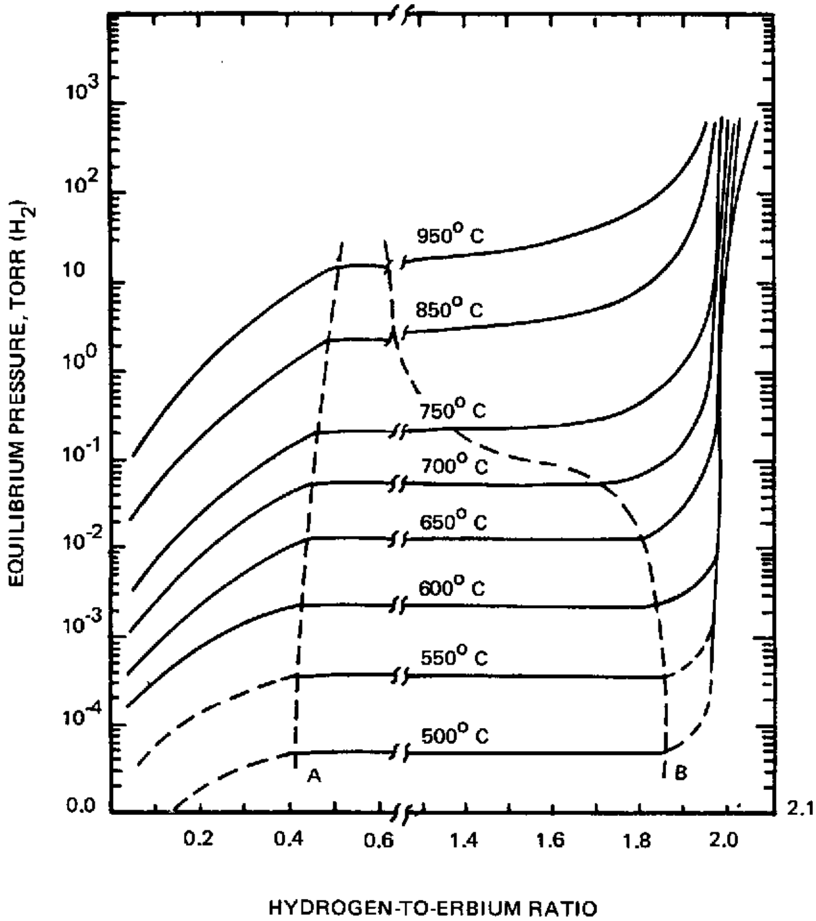



Figure 1. Family of Isotherms in the Erbium/Hydrogen System

Existing ultrahigh-vacuum calibration systems are usually large expensive units, and are not easily integrated with most experimental apparatus. A new small inexpensive calibration unit is mounted directly on the experimenter's primary apparatus. It utilizes the metal/gas binary system of erbium/hydrogen, in a small mountable assembly, as a secondary standard for pressures in the range $1 \times 10^{-6}$ to $3 \times 10^{-10}$ torr ($H_2$).

The property of the erbium/hydrogen system that makes it useful is the loss of pressure dependence that occurs when the system enters a two-phase region (see Figure 1). Initially, hydrogen is added to erbium solid solution until, at a particular ratio of hydrogen to erbium, the dihydride phase appears (point A). The further addition of hydrogen results in a pressure plateau until all the erbium solid becomes dihydride (point B). From point A to point B, for a given temperature, pressure is independent of the ratio of hydrogen to erbium.

The calibration unit is shown in Figure 2. Approximately 0.5 g of erbium powder is located in the ceramic ($Al_2O_3$) tube heater. Precautions must be taken to assure a constant temperature equilibrium.

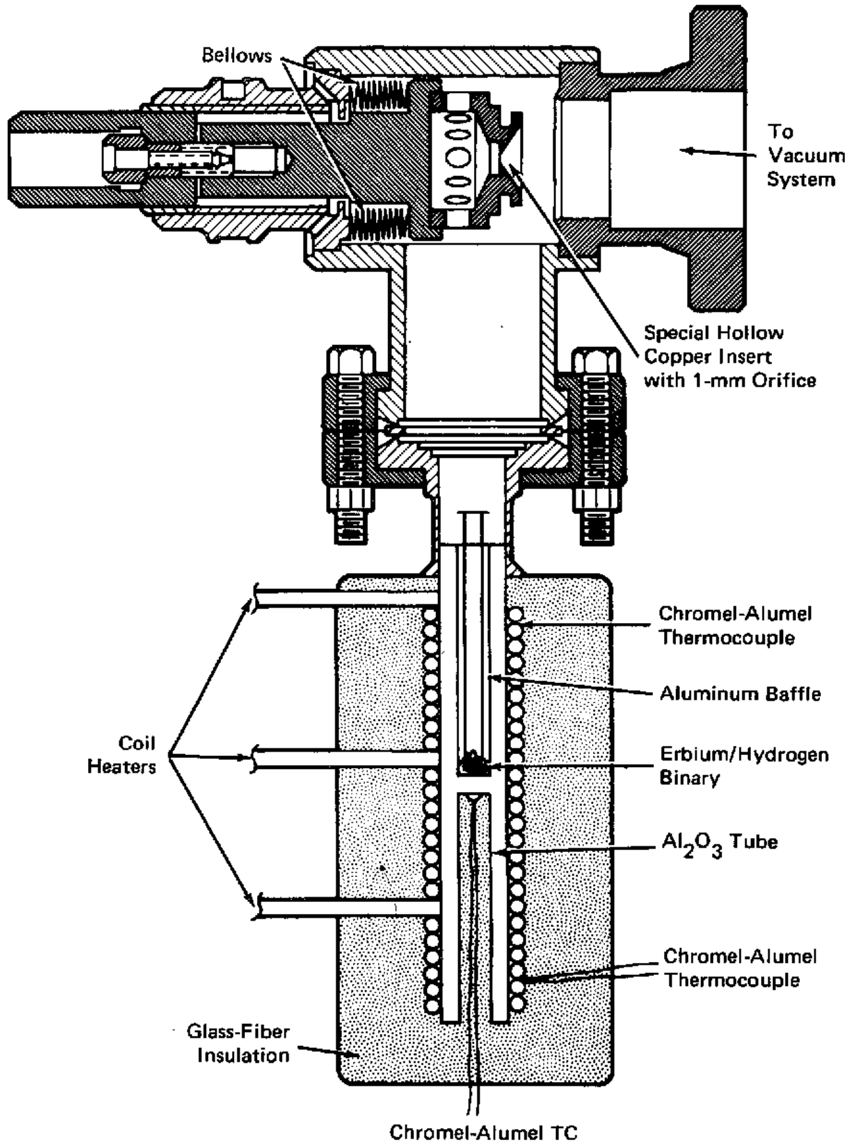



Figure 2. Metal/Gas Calibration System

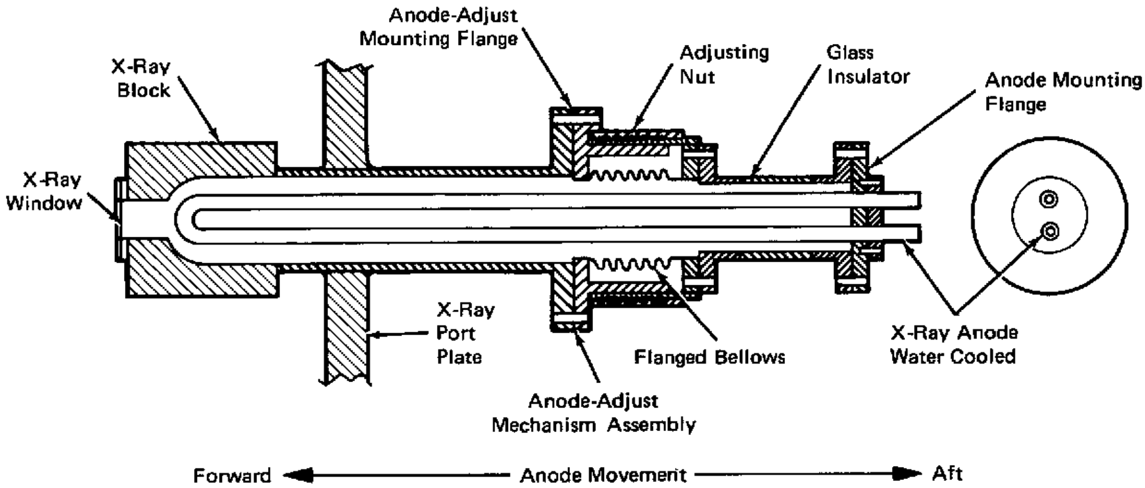
Hydrogen gas enters through a 1-mm orifice to ensure ample time to reach equilibrium.

This unit has been mounted on an experimental apparatus, and tests have been made over a range of pressures from $10^{-5}$ to $10^{-10}$ torr ($H_2$). Results are in good agreement with calculations. The repeatability of data is good, even after the metal/gas is exposed to atmospheric pressure. The simplicity, small size, and low cost of this unit add to its usefulness as a secondary standard.

Source: R. A. Outlaw and R. E. Stell
Langley Research Center
(LAR-10862)

*Circle 12 on Reader Service Card.*

## X-RAY ANODE FINE ADJUSTMENT




X-Ray Anode Fine Adjustment Mechanism

No allowance for fine-position adjustment is made in the conventional design of an X-ray anode in a vacuum environment. The X-ray anode must be turned off for adjustments, and only coarse adjustments can be made. This method is time consuming and inaccurate.

A mechanism has been developed which provides a fine-controlled linear movement of the energized anode. The mechanism contains a flanged bellows (see figure) with a threaded slide and a threaded tube, called the adjusting nut. As the adjusting nut is rotated, the bellows are compressed or extended. This mechanism could be used as a movable vacuum feedthrough.

Source: Vincent G. Canali
Goddard Space Flight Center
(GSC-11259)

*No further documentation is available.*

# Patent Information

The following innovations, described in this Compilation, have been patented or are being considered for patent action as indicated below:

**An Efficient Heat-Recovery System** (Page 2) MFS-22506

Inquiries concerning rights for the commercial use of this invention should be addressed to:

Patent Counsel
Marshall Space Flight Center
Code A&PS-PAT
Marshall Space Flight Center, Alabama 35812

**Cryogenic Surface-Tension/Start Tank** (Page 12) MFS-21566

Inquiries concerning rights for the commercial use of this invention should be addressed to:

Patent Counsel
Marshall Space Flight Center
Code A&PS-PAT
Marshall Space Flight Center, Alabama 35812

**A Secondary Standard for Ultrahigh Vacuum** (Page 18) LAR-10862

This invention has been patented by NASA (U.S. Patent No. 3,780,563). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to:

Patent Counsel
Langley Research Center
Code 456
Hampton, Virginia 23665